Home Dehydrators For Food Preservation

A method for drying and storing foods for home use is described. A study of convection and forced-air dehydrators disclosed that the forced-air type has the ability to dry faster and is the more efficient dryer at little extra cost. Safe food storage is assured with the use of humidity indicating cards. These cards, which contain a variety of absorbed cobalt chloride solutions, indicate a varied range of relative humidities (8-80 percent). The card readings were successfully correlated with water activity.

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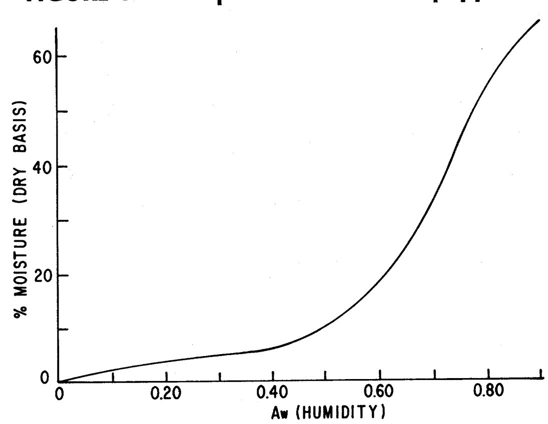
Introduction

More homeowners and small farmers are growing gardens to combat the rising price of fruits and vegetables. These crops must be stored or preserved by some means to extend their useful life until the next harvest. A recent study showed that at least one fourth of these gardeners practiced some type of food preservation (Klippstein, 1977). Dehydration is the oldest method of food preservation but it is the least practiced by home gardeners. It has some advantages over canning and freezing primarily decreased weight and bulk.

Dehydration is not complicated but the process itself, predrying and drying, takes time and requires attention. Moisture content and/or water activity is used as the criterion for drying and storage safety because the effectiveness of drying relies on the assurance that microorganisms are unable to grow and cause spoilage below A_w 0.6 (Nickerson and Sinskey, 1972; Troller, 1980). Drying or reduction of water activity (percent relative humidity) of the food pieces in the dehydrator is rapid to about 35% moisture (dry basis), a water activity (A_w) of approximately 0.7 (Figure 1). Drying progresses slowly from this point to an A_w of 0.6 or less.

FIGURE 1. Adsorption isotherm for peppers.



Fruits and vegetables require careful preparation before drying. Clean, ripe, sound produce must be peeled in most cases, then cut small enough to dry in a reasonable time. Two additional steps, blanching to inactivate

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TABLE 1
Relative humidity of saturated salt solutions at 77°F (25°C)

Salt solution	Percent relative humidity	Reference
Lithium chloride	12.0	Wexler and Hasegawa (1954)
Potassium acetate	22.5	Houston and Kester (1954)
Potassium carbonate	43.7	Houston and Kester (1954)
Ammonium nitrate	63.5	O'Brien (1948)
Sodium chloride	75.8	Wexler and Hasegawa (1954)

harmful enzymes and sulfiting to retard nonenzymatic browning, are essential for protection during drying and for prolonged safe storage (Duckworth, 1966).

Commercial drying companies have whetted the public's appetite by introducing and marketing many dehydrated foods. Home dehydration is a way to make and preserve these same kinds of foods on a small scale. Sun (solar drying) and occasionally drying in the kitchen oven are the most utilized. Home dehydrators are relatively new small appliances that can be used to dry, and produce acceptable products. The dehydrators are not costly.

Dehydrators may be purchased ($125 to $400) in many sizes and types or may be built from available plans ($50) (Kirk, 1977). All dehydrators provide a heat source and vents to exhaust moist air. Simpler units depend on natural convection. A more complex and efficient type has a forced-air system that provides more even heating and removes the moist air from the drying area rapidly.

This paper describes a method of home dehydration, examines the efficiency of home dehydrators, and suggests a means of controlling bacteriological growth.

Experimental Work

Pretreatments

The commodities selected for study were apples, carrots, mushrooms, peppers, and white potatoes. The apples, carrots, and potatoes were peeled; each commodity was cut into a convenient size, either cubes or wedges (1 cm maximum cut dimension). All commodities, except apples, were steam blanched 3 to 5 minutes to inactivate peroxidase and catalase. The food pieces were immersed in a 0.5 percent $NaHSO_3$ solution for 1 minute and drained.

Dehydrator Studies

Two natural convection dryers (one built in-house, one commercially available model) and two forced-air (one built in-house and a commercial model) were tested for their convenience, and uniformity and rate of drying. For the tests, food pieces were placed onto the dehydrator trays a single layer deep, weighed (before and during drying), and dried. Drying temperatures were controlled at 65°C (150°F) maximum. The air flow rates of the forced-air dehydrators were 6.25 m^3/min (220 cu ft/min) for the in-house and 3.60 m^3/min (125 cu ft/min) for the commercial model.

In addition, an attempt was made to improve the efficiency of the in-house forced-air model (Kirk, 1977). For this study, potatoes (1 cm, French fry cut) were dried in the dehydrator with its five dryer trays arranged in two different series. In the first series, all trays were placed in their normal positions with the largest tray (#1) at the top and the trays graduated to the smallest at the bottom (#5). For the second, the trays were relocated (5, 4, 1, 3, 2 from top to bottom); the large trays were placed nearest the heat source with the exception of tray #1 (the largest). This tray would not fit into the dryer below the center drying position.

Commodity Tests

Kirk's forced-air dehydrator was selected for drying the commodities (apples, carrots, mushrooms, peppers, and potatoes) for testing. Weighings were made throughout the drying tests on kitchen or nursery-type scales with 4 oz graduations from 0 to 25 lb and on a laboratory balance with a sensitivity of ±0.1 g. Drying was considered complete when the food contained less than 10% moisture (A_w < 0.6). Water activity was determined for the dried products by using salt sensors (Stoloff, 1978). The dried products were put into sample jars or plastic bags along with a Humidial Corporation (495 Mt. Vernon Avenue, Colton, CA 92324) humidity indicator card, sealed, and stored at 3.3°C. The humidity cards were checked periodically. Adsorption isotherms were constructed for the dried products. The data for each isotherm were developed at the humidities indicated in Table 1.

Humidity Card Tests

Humidity indicating cards contain strips of blotting paper with each strip impregnated with a different cobalt salt solution and additives. Strips are available which will indicate relative humidity from 8 to 80%. The reliability of the indicator cards for predicting water activity was tested by comparing their readings with the salt sensor A_w values. The accuracy of the lower A_w range was tested by placing indicator cards in sample jars of dried food pieces and recording the percent relative humidity. These humidity readings were compared to the A_w for the same samples evaluated by the salt sensor method. In another test, the entire range of the indicator cards (8 to 80 percent) was evaluated for accuracy in specifying water activity. Ground dried apple samples (2 percent moisture) were exposed for 6 weeks to five humidities (saturated atmospheres) produced by solutions of different salts. The five apple samples were placed in separate sealed jars, each with a humidity card. Humidity card readings were recorded, and the water activity of each apple sample was determined by the sensor method.

Analytical Work

Moisture. Moisture content was determined by the standard AOAC method. All samples were dried at 70°C under vacuum for 16 hours. Results are given on a wet basis.

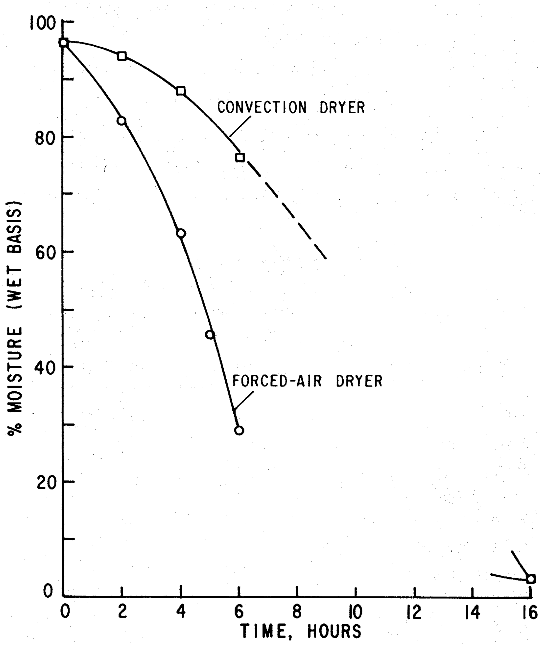
Water Activity. Water activity (A_w) was determined in two steps. First, a selected LiCl sensor was placed in a closed atmosphere with the sample and the electrical resistance of the atmosphere was measured on an electric hygrometer. If the reading was between a scale reading of 5 and 95 the correct sensor had been selected. A preliminary A_w value was obtained by converting the meter reading to water activity by using a humidity calibrating chart supplied by the manufacturer of the selected sensor.

TABLE 2
Water composition of some foods[a]

Food (raw)	Percent solid	Percent moisture
Apples	15.6	84.4
Apricots	14.7	85.3
Asparagus	8.3	91.7
Bananas	24.3	75.7
Bean lima	32.5	67.5
Bean green	9.9	90.1
Bean wax	8.6	91.4
Beets	12.7	87.3
Blueberries	16.8	83.2
Broccoli	10.9	89.1
Cabbage	7.6	92.4
Carrots	11.8	88.2
Celery	5.9	94.1
Cherries (sour)	16.3	83.7
Cherries (sweet)	19.6	80.4
Corn (white or yellow)	27.3	72.7
Cranberries	12.1	87.9
Cucumbers	21.0	79.0
Eggplant	7.6	92.4
Grapes	18.4	81.6
Mushrooms	9.6	90.4
Onions	10.9	89.1
Peaches	10.9	89.1
Pears	16.8	83.2
Peas	16.7	83.3
Peppers (sweet) (green)	9.3	90.7
Peppers (sweet) (red)	9.3	90.7
Pineapples	14.7	85.3
Plums	18.9	81.1
Potatoes	20.2	79.8
Rutabagas	13.0	87.0
Squash (summer)	6.0	94.0
Squash (winter)	14.9	85.1
Tomatoes	6.5	93.5
Turnips	8.5	91.5

[a] From USDA Handbook No. 8.

FIGURE 2. Convection and forced-air dehydrator drying curves for peppers.



In the second step, the selected LiCl sensor was calibrated. The same method was used, but the sample was replaced with a saturated salt solution of known water activity. The difference in A_w obtained from the chart for this calibration was added to or subtracted from the preliminary A_w to give the corrected, or actual, A_w.

Adsorption Isotherms. The products were freeze dried, ground in a blender to pass through a 20-mesh screen, and then exposed to atmospheres of different relative humidity until the corresponding equilibrium moisture contents were reached. These atmospheres, ranging in relative humidity from 12.0 to 75.8 percent at 25°C (77°F) were prepared by placing saturated salt solutions (Table 1) in the bottom section of desiccators.

Home Dehydrator's Drying Aid

Final drying weights (10 percent dry basis) were obtained as follows: food pieces were placed on the dehydrator trays a single layer deep and weighed (net weight). The trays were placed in the dehydrator at 65°C (150°F). During drying, the end weight (net) was determined by multiplying the original weight (net) by the original solids in percent (Table 2) and dividing by 91, the percent solids equivalent to 9 percent moisture. During drying, trays were removed periodically and weighed. When the net weight of any tray equaled or was less than the calculated end weight of that tray, the food pieces were at 9% moisture or less and the product was considered dry. The dried product was placed in sealed containers with an indicator card. The card was read in 2 days. If the card reading was 60 percent or less, corresponding to an $A_w < 0.6$, the product was dry. If the reading was higher, the product was returned to the dehydrator for additional drying. The indicator card test was repeated.

TABLE 3
1 cm × 1 cm French fry potatoes dried @ 65.6°C

	Tray 1 % moisture		Tray 2 % moisture		Tray 3 % moisture		Tray 4 % moisture		Tray 5 % moisture	
Time (in hours)	Normal (top)	Relocated (center)	Normal (next to top)	Relocated (bottom)	Normal (center)	Relocated (next to bottom)	Normal (next to bottom)	Relocated (next to top)	Normal (bottom)	Relocated (top)
0	78.63	78.10	78.63	78.10	78.63	78.10	78.63	78.10	78.63	78.10
2	72.20	73.00	72.75	72.44	72.79	73.32	73.98	73.94	73.27	72.16
3-1/2	66.68		68.05		69.02		69.12		68.78	
4		62.83		62.27		64.74		66.21		60.08
4-1/2	58.61		63.19		64.66		64.18		64.24	
5		52.66		52.42		56.08		57.61		48.98
5-1/2	55.68		58.03		59.85		58.90		59.16	
6		42.07		41.74		46.49		47.69		37.67
6-1/2	47.89		50.13		52.70		50.96		51.64	
7		27.85		27.69		33.17		33.68		24.30
7-1/2	39.26		40.68		43.26		41.33		41.30	
8		13.93		13.53		18.33		17.90		12.90

TABLE 4
Comparison of weights of potatoes measured on laboratory and kitchen balances

Tray number	Laboratory	Kitchen	% Deviation
	Beginning weights (g)		
1	1236.3	1307.5	5.8
2	1182.2	1163.2	1.6
3	988.4	956.1	3.3
4	971.4	940.5	3.2
5	769.4	747.6	2.8
	End weights (g)		
1	285.4	282.3	1.1
2	276.7	283.7	2.5
3	227.9	232.6	2.1
4	221.9	221.3	0.0
5	176.3	181.6	3.0
	% End moisture		
1	3.47	3.70	0.23
2	3.42	3.28	0.14
3	3.47	3.29	0.18
4	3.50	3.40	0.10
5	3.49	3.29	0.20

Results and Discussion

Dehydrator Studies

One natural convection dryer (the commercially available model) was eliminated after two tests because the heating elements were so arranged that the products scorched unless the dryer was constantly tended. The other natural convection dryer (built in-house model) performed well but because it took 1.4 times as long or longer to dry the commodities studied as Kirk's forced-air dehydrator (Figure 2), further evaluations were discontinued. The products from both dryers, the in-house convection model and Kirk's forced air dehydrator, were of the same quality.

The two forced-air units were compared. Products in the commercial unit dried unevenly because of the locations of the heating elements and the fan. Dryers of this type require frequent tray rotation or the material on one side of the dehydrator tray will dry much faster than the other three sides. Kirk's forced-air model dried foods relatively fast, without tray rotation, and was the best of the four dryers, based on speed and product quality. However, the drying rate was improved when the drying trays were rearranged (Table 3). This rearrangement forced the air to be directed through the trays instead of passing around them.

Commodity Tests

Final moistures corresponding to a 0.6 A_w were determined for the commodities from adsorption isotherms. The isotherms for the five commodities indicate that a wet moisture of 9% (10% dry basis) was sufficient to give an $A_w < 0.6$. The pepper isotherm (Figure 1), which was almost identical to the other four isotherms, illustrates this. At 9 percent moisture (wet basis) the A_w was 0.5 and when this moisture was achieved, the products were considered dry.

During the commodity tests, the products were weighed on two types of balances, a laboratory balance (sensitivity ± 0.1 g) and a kitchen or nursery balance (4 oz graduations to 25 lb). The laboratory balance was used as the standard. The kitchen balance deviated from the standard by 0 to 5.8 percent in the weighings (Table 4). However, the calculated end-

TABLE 5
Comparison of water activity and humidity card reading

Commodity	A_w sensor	A_w humidity card	% Moisture dry basis
Mushroom	0.228	0.25	5.0
Pepper	0.300	0.30	4.5
Carrot	0.255	0.25	4.5
Apple	0.179	0.20	4.0
Potato	0.149	0.15	4.0

TABLE 6
Comparison of water activity and humidity card readings at various humidities with apples as the medium

Salt	Humidity generated	A_w sensor	Card reading
Lithium chloride	0.12	0.15	0.15
Potassium acetate	0.22	0.25	0.22
Magnesium chloride	0.32	0.29	0.32
Sodium bromide	0.58	0.56	0.58

moisture values differed only 0.10 to 0.23 percent (Table 4). Although a laboratory balance of low sensitivity is preferred, a kitchen or nursery type balance is accurate enough when dehydrating foods at home. In these tests, potatoes were dried 15 hours by activating the dehydrator at 2 am and this length of drying produced the low moisture products.

Humidity Card Tests

The results of the two humidity card tests are shown in Tables 5 and 6. The true water activities are listed as salt sensor values. The humidity indicating card readings are within 0.03 of the true water activity and can be safely used to determine A_w. The reading on a humidity card stored with dried food pieces in plastic bags at 3.3°C (38°F) is in reality the A_w of the food. When the A_w increases to 0.6 the product must be used immediately or thrown away.

Conclusions

Kirk's forced-air dehydrator or a similar design is recommended. This dehydrator gives fast, even drying without frequent tending. Products will dry in a reasonable time to an adequately low moisture (9 percent) for storage. However, for a better drying rate, the dehydrator should be redesigned to prevent hot air from by-passing the trays. Microbially safe storage ($A_w = 0.6$) is assured with the use of humidity indicating cards by checking their values periodically. Kitchen or nursery balances can be used, but a low-sensitivity laboratory balance is preferred.

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